METHODS OF DETERMINING AND PLOTTING METER CAPACITIES AND SOME RESULTS[1]

By Fred B. Nelson

The relative merits of meters may, in general, be shown by a comparison of their accuracy, sensitiveness, durability and capacity.

Accuracy is an important, in fact, an essential feature easily determined by test and the only one to which the average city gives serious consideration. Yet there is hardly a meter on the market that cannot meet the usual accuracy requirements, particularly the positive displacement type of meter in which accuracy, only, calls for little refinement of design beyond an accurate fit of the piston in its chamber. The feature of accuracy, therefore, gives very little as a basis of comparison of the different makes and types and creates little or no competition.

Sensitiveness or ability to register low flows is a feature which represents revenue in the registration of the small and often continuous flows which exist on nearly all classes of services, and is a feature in which the different makes and types differ more and upon which more competition could be established by city requirements.

Durability is not so susceptible of determination by test, but accelerated tests can be arranged which, in a short time, will more or less duplicate the service wear of years, and in justice to the efforts of meter companies in putting out durable products, greater recognition of this quality should in some way be made by more specific requirements.

Capacity, the fourth feature, is one which is susceptible of exact determination and one in which surprising differences are revealed between the different makes in the same size and often between the proportional capacities of the different sizes of the same make. It is a feature which has a direct bearing on the service pressures maintained and requires careful and intelligent designing if high capacity and relatively low loss of head are to be secured and the other essential features retained. Yet it is a feature that is quite generally

[1] Read before the Richmond Convention, May 10, 1917.

ignored and little incentive is held out to meter companies to perfect their products in this direction.

Recent meter testing of the department of water supply, gas and electricity of New York has been conducted with considerable attention to pressure loss and capacity, and the author feels that certain features of the methods used and the results obtained may be of interest.

The apparatus used consists essentially of the following: A mercury U-tube so connected by tubing with the inlet and outlet of the meter as to measure directly by the head of mercury the pressure loss between those points at the different rates of flow; tank scales for determining by weight the actual volume of water passed; a regulating valve for adjusting rates of flow; a quick-acting valve for starting and stopping the tests with a minimum of flow below the adjusted rate; and a stop watch for the accurate determination of the duration of flow.

The three elements, pressure loss, volume and time are thus obtained by single readings of apparatus having a very small percentage of error and the results are surprisingly consistent. The use of the mercury column in particular, by giving one direct and sensitive reading of the pressure difference, eliminates the mechanical inaccuracies of pressure gauges and many possible errors, due to the attempt to make simultaneous observations of two gauges, apply corrections and substract their readings. One pound per square inch of pressure corresponding to 0.455 inch of mercury deflection enables a very accurate direct reading of the pressure loss even on very low flow, which could hardly be taken with any degree of accuracy by subtracting the readings of two gauges.

Apparatus embodying these features was assembled and used by the author in making pressure-loss tests on all disc meters on the New York approved list and others submitted for approval in all sizes up to and including 2 inches.

In studies of pressure loss and capacity, the author feels that it may be of interest to call attention to some decided advantages in the use of logarithmic paper in plotting pressure-loss data and some features of pressure loss that are by that means illustrated. This paper is so ruled that equal distances, horizontally and vertically, correspond to the logarithms or powers of the numbers given on the ruling, so that in plotting any data in which one value varies as a fixed power of another, the graph or curve is that of the constant

ratio between the powers of the indicated values and is therefore a straight line.

The advantage in the use of this paper in plotting pressure loss is due to the fact that the pressure loss in meters varies very closely as the square of the discharge, so that if discharge values be plotted horizontally and corresponding pressure losses vertically, the points will define a straight line having a slope of one horizontal to two vertical. From this it follows that from but one correct determination of pressure loss at any given rate of flow, the pressure loss of all other rates of flow is at once determined by drawing a straight line through the one plotted point at this 2 to 1 angle (compare figs. 1 A and 1 B).

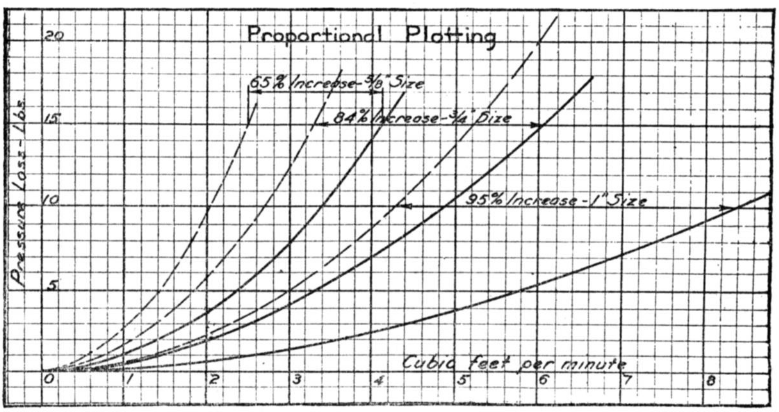

FIG. 1 A. IMPROVEMENT IN CAPACITY AND DECREASE OF PRESSURE LOSS EFFECTED BY REDESIGNING AND ENLARGING OF WATERWAYS WITHOUT CHANGE IN DISK SIZE; PROPORTIONAL PLOTTING

The slope of this line (2 to 1) represents the general law of pressure loss in disc meters and is therefore the same for all makes and all sizes, and the lines or graphs for individual meters of all makes and sizes are parallel (fig. 5). In the tests made, such a line has frequently been drawn from a determination at but one flow and afterward a different desired rate of flow has been adjusted to within 1 or 2 per cent by a turn of the regulating valve, bringing the mercury column to the pressure loss corresponding to the intersection of that line with the desired rate. The straight line also serves as a check against all errors of computation or reading where more than one determination of pressure loss is made, as the points must theoretically fall on

a straight line and any errors in results are at once conspicuous by the points plotting up off the line.

The disadvantage of the logarithmic plotting is that the values are not shown in their true proportions. Where, however, a proportional curve is needed it can easily be constructed in a few moments

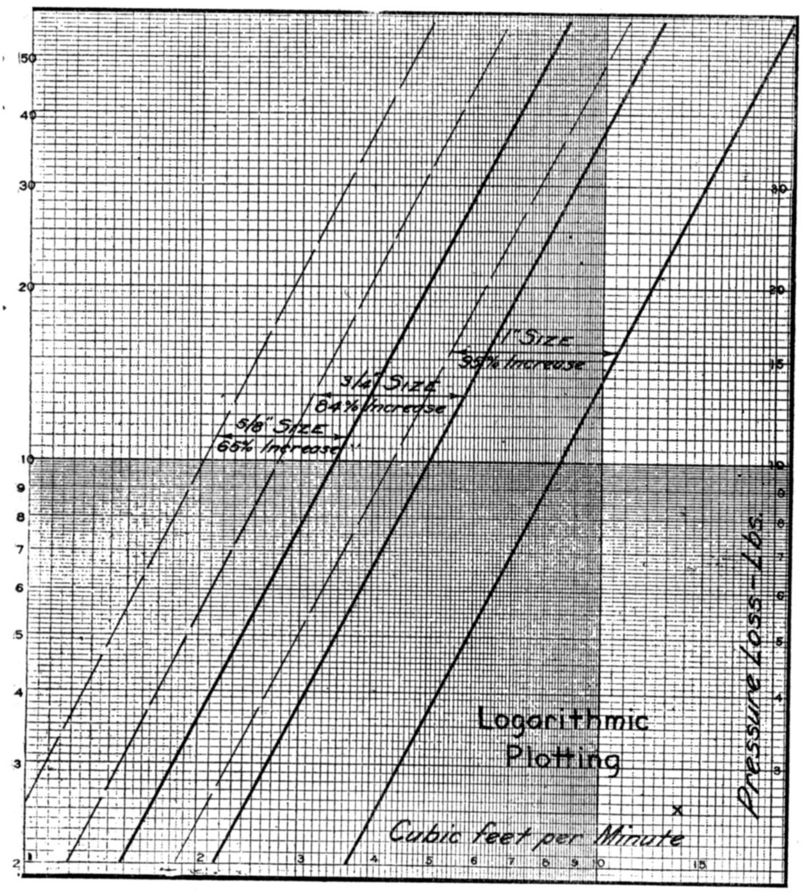

FIG. 1 B. SAME DATA AS FIG. 1 A—*Logarithmic Plotting.*

by plotting any desired number of points taken from the logarithmic line, with a consequent saving of a great amount of time otherwise required to obtain a sufficient number of test points in the ordinary way, including the essential low flows, to define the pressure loss curve well.

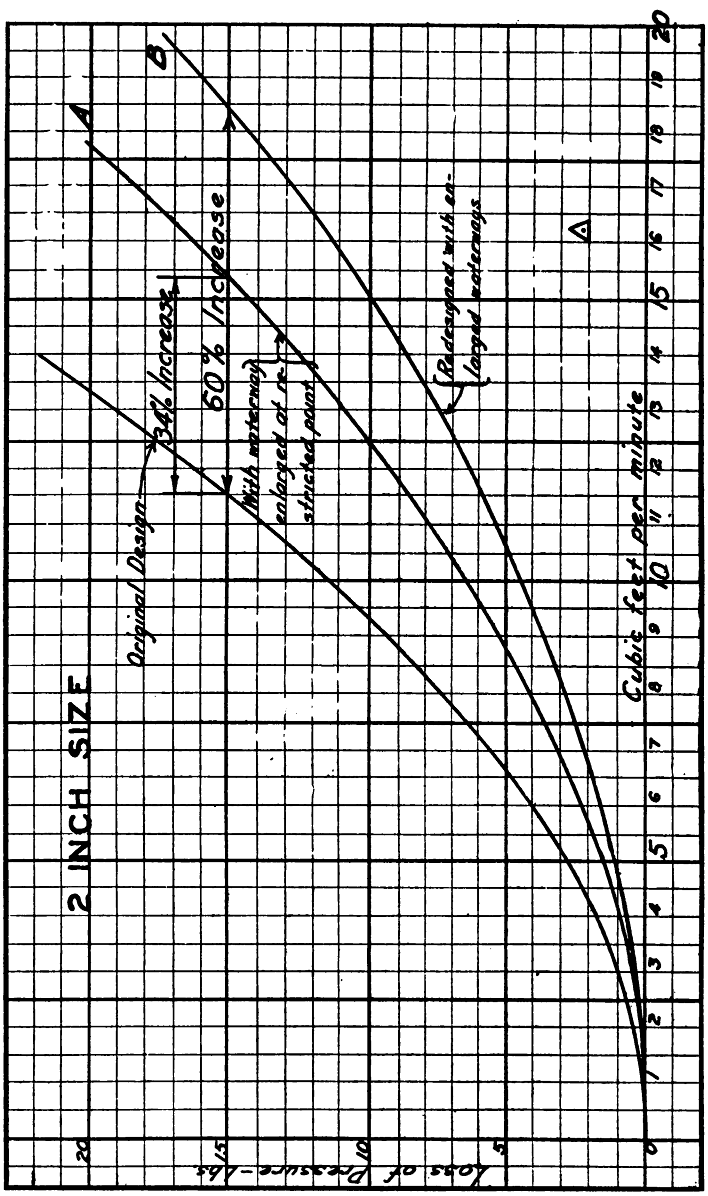

FIG. 2 A. IMPROVEMENT IN CAPACITY AND DECREASE OF PRESSURE LOSS EFFECTED BY IMPROVED CHANGES ORIGINAL METER, CURVE A, AND BY ENLARGED WATERWAYS EMBODIED IN IMPROVED COMMERCIAL TYPE, CURVE B

As a point of interest the slope of the straight line graph on logarithmic paper verifies the correctness of the formula that friction loss varies as the square of the flow. In the actual tests made this has been indicated to vary from the 1.94th power to the 2nd power of the rate of flow.

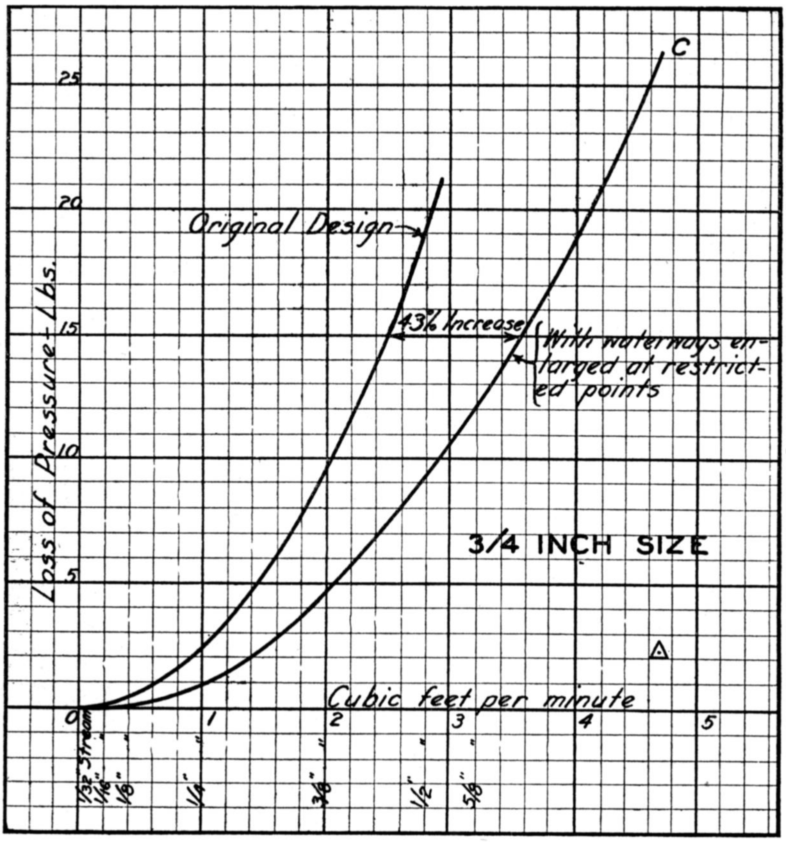

FIG. 2 B. IMPROVEMENT IN CAPACITY AND DECREASE OF PRESSURE LOSS EFFECTED BY ENLARGED WATERWAYS IN IMPROVED COMMERCIAL TYPE, CURVE C

Convenient use may be made of the logarithmic method of plotting in comparing the relative capacities of the different sizes in any one make (fig. 3—A, B, C and D. If diameters be plotted horizontally and corresponding areas of orifices vertically, the plotted points

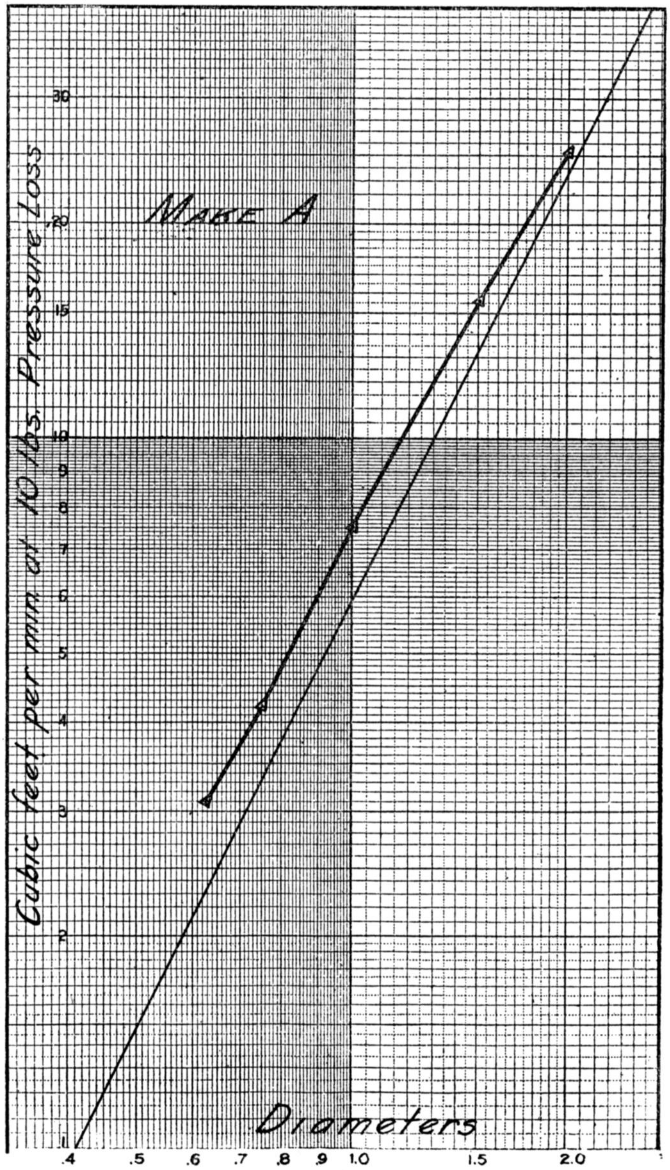

Fig. 3 a. Proportional Capacities of Meters at 10 Pounds Pressure Loss Compared with Proportional Discharge of Similar Sized Orifices under Fixed Head; Well-Proportioned Meter of High Capacity

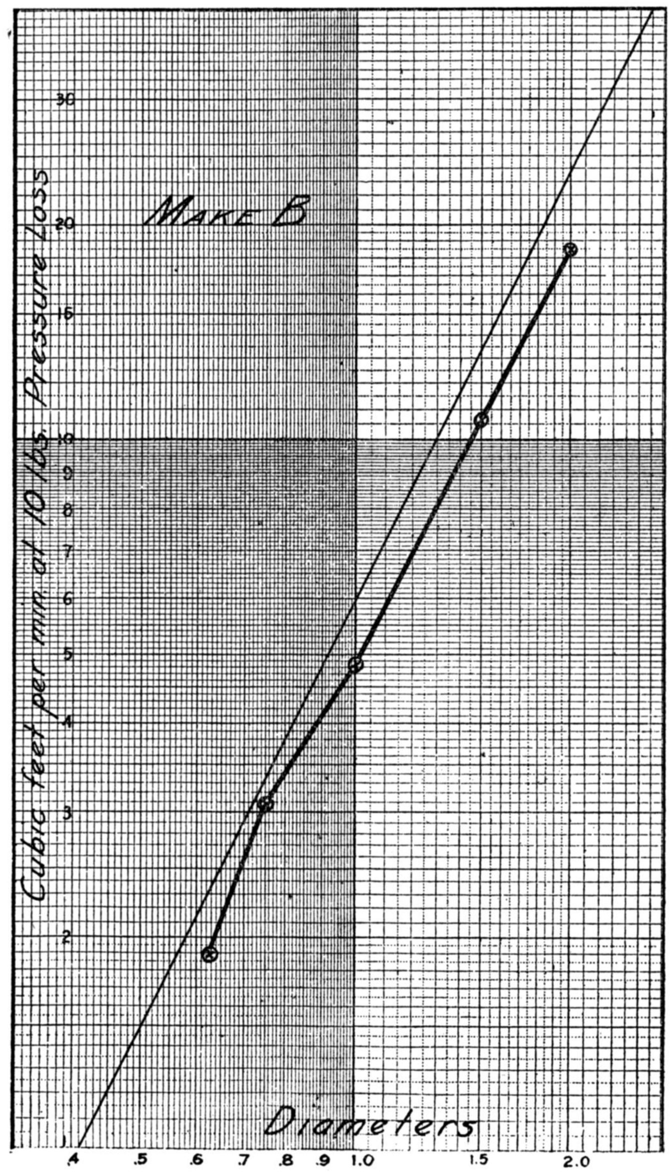

FIG. 3 B. PROPORTIONAL CAPACITIES OF METERS AT 10 POUNDS PRESSURE LOSS COMPARED WITH PROPORTIONAL DISCHARGE OF SIMILAR SIZED ORIFICES UNDER A FIXED HEAD; WELL PROPORTIONED METER OF LOW CAPACITY

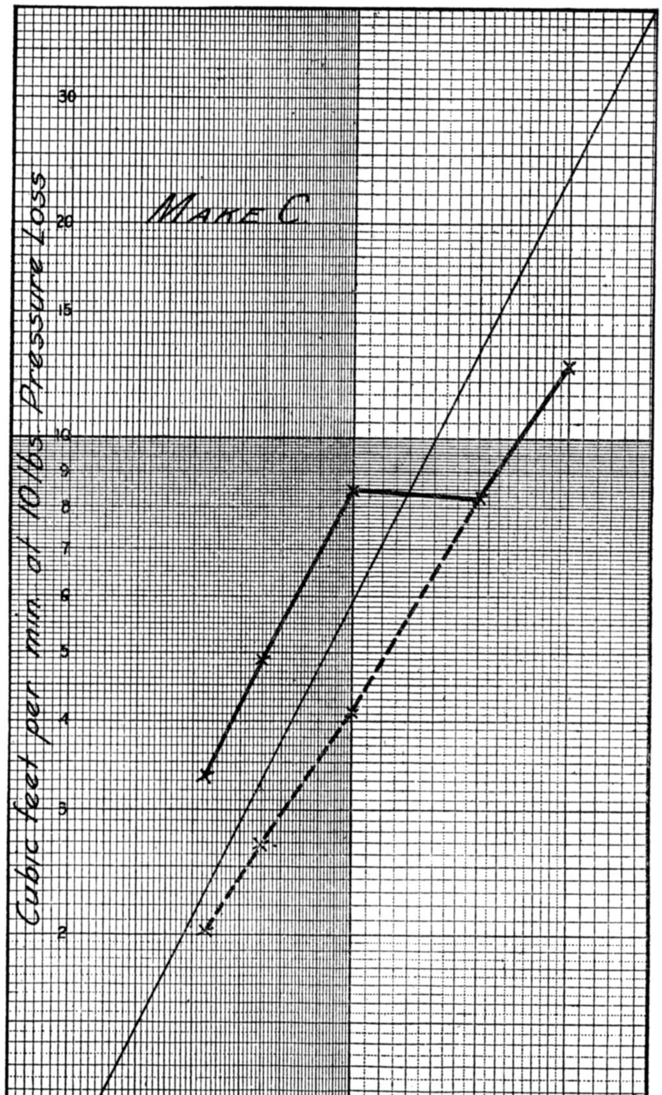

Fig. 3 c. Proportional Capacities of Meters at 10 Pounds Pressure Loss Compared with Proportional Discharge of Similar Sized Orifices under a Fixed Head

The full line shows the present proportional capacities of improved $\frac{5}{8}$, $\frac{3}{4}$ and 1 inch sizes as illustrated in Figure 1, and the dotted line shows the capacities of the original design.

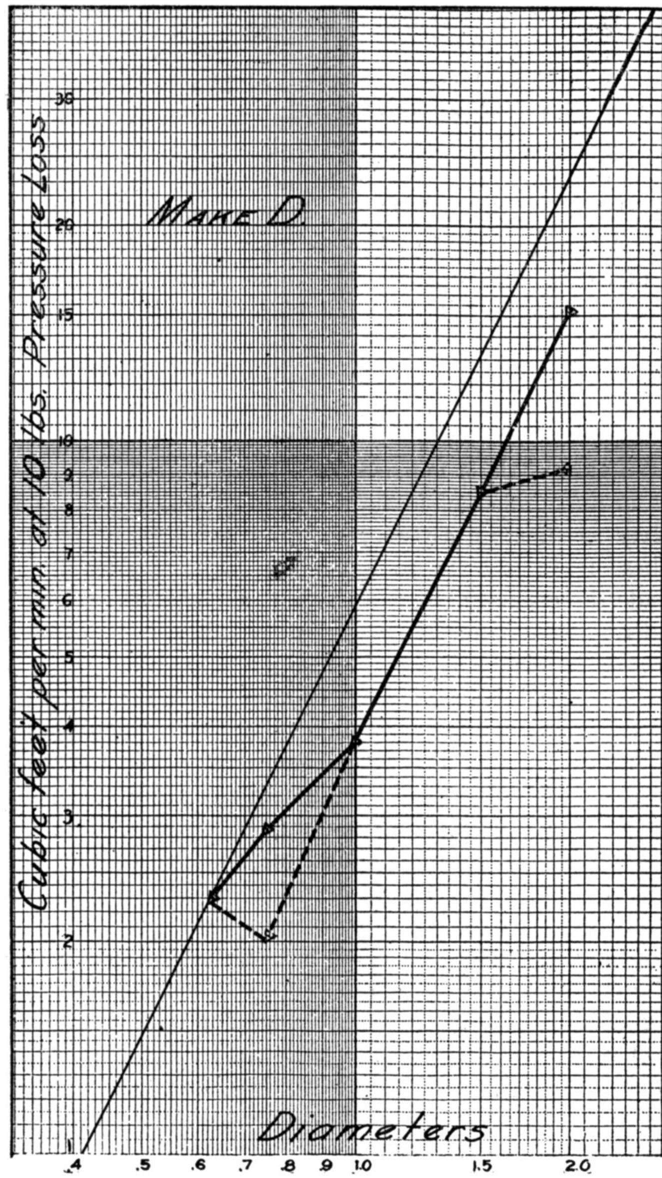

FIG. 3 D. PROPORTIONAL CAPACITIES OF METERS AT 10 POUNDS PRESSURE LOSS COMPARED WITH PROPORTIONAL DISCHARGE OF SIMILAR SIZED ORIFICES UNDER FIXED HEAD

Dotted lines show the variation from ideal proportions in the original designs which were rectified by the increases of capacity shown in Figures 2 A and 2 B.

will define a straight line with a slope of two vertical to one horizontal, the area and consequent discharge under a fixed head varying as the 2nd power of the diameter. Using the same horizontal scale of diameters, the cubic feet per minute discharge of each size of meter may be plotted vertically. If now it be assumed that the capacities of one type and make of meter should vary in proportion to orifices of corresponding sizes, then these plotted capacities should also define a straight line which should be parallel to that representing areas.

By such studies of capacities it is shown that a very wide variation exists in the relative capacities of the different sizes of some makes (fig. 3) as well as an extremely wide variation in the capacities of different makes in the same size (figs. 4 and 5).

There are a number of features of design which at once suggest themselves as affecting capacity more or less directly and in some cases these features seem to have been sadly neglected. In the tests made the capacity seems to be but slightly affected by size of disc and number of mutations, except, possibly, in cases where the total friction loss is small and the disc size and speed enter in as an appreciable part of the total loss. In most cases, the size and shape of the waterways have far more direct bearing on the capacity. In the construction of pumping machinery, great emphasis is placed on easy curves of waterways and very gradual changes of direction in the flow of water, particularly on suction lines where but little friction loss can be permitted. Some meters seem to have been designed with the same care and attention to these details, while in others very little attention seems to have been given. Frequently waterways are so restricted as to act as partially closed valves and often the course of the water is abruptly reversed, both features resulting in a serious increase of pressure loss and decrease of capacity. On the tests that have been made, instances have been noted where the capacity of the meter has been increased from 34 to 95 per cent merely by a change or redesigning of the waterways, leaving the size of the disc, number of mutations, etc., the same (see figs. 1 and 2).

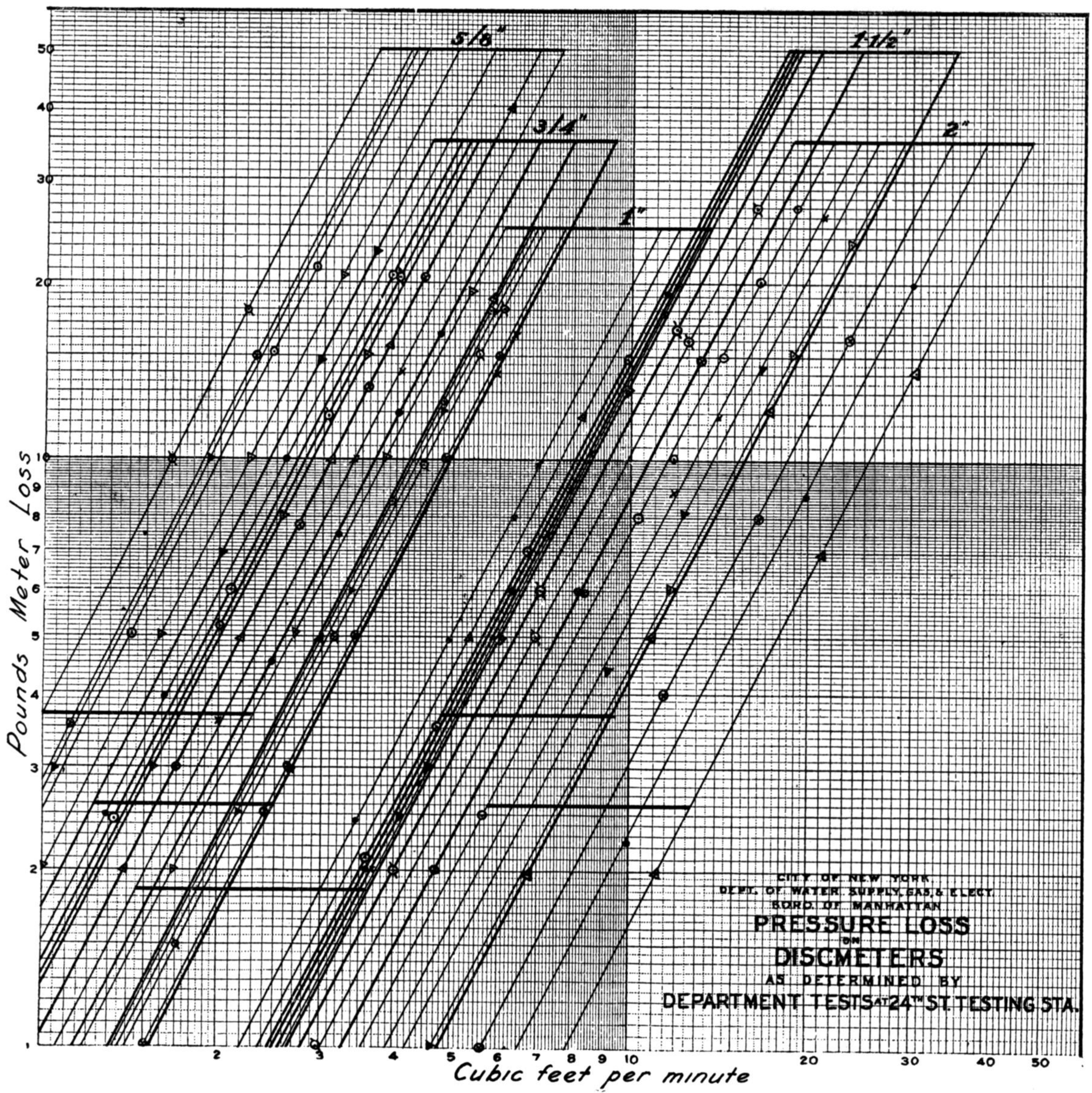

FIG. 5. COMPARATIVE PRESSURE LOSS OF DIFFERENT MAKES OF METERS FROM 5/8 TO 2 INCHES IN SIZE, INCLUSIVE

Showing the lack of uniformity in capacity corresponding with the given sizes. (Each individual make in the various sizes may be identified by the shape of points used in plotting.)

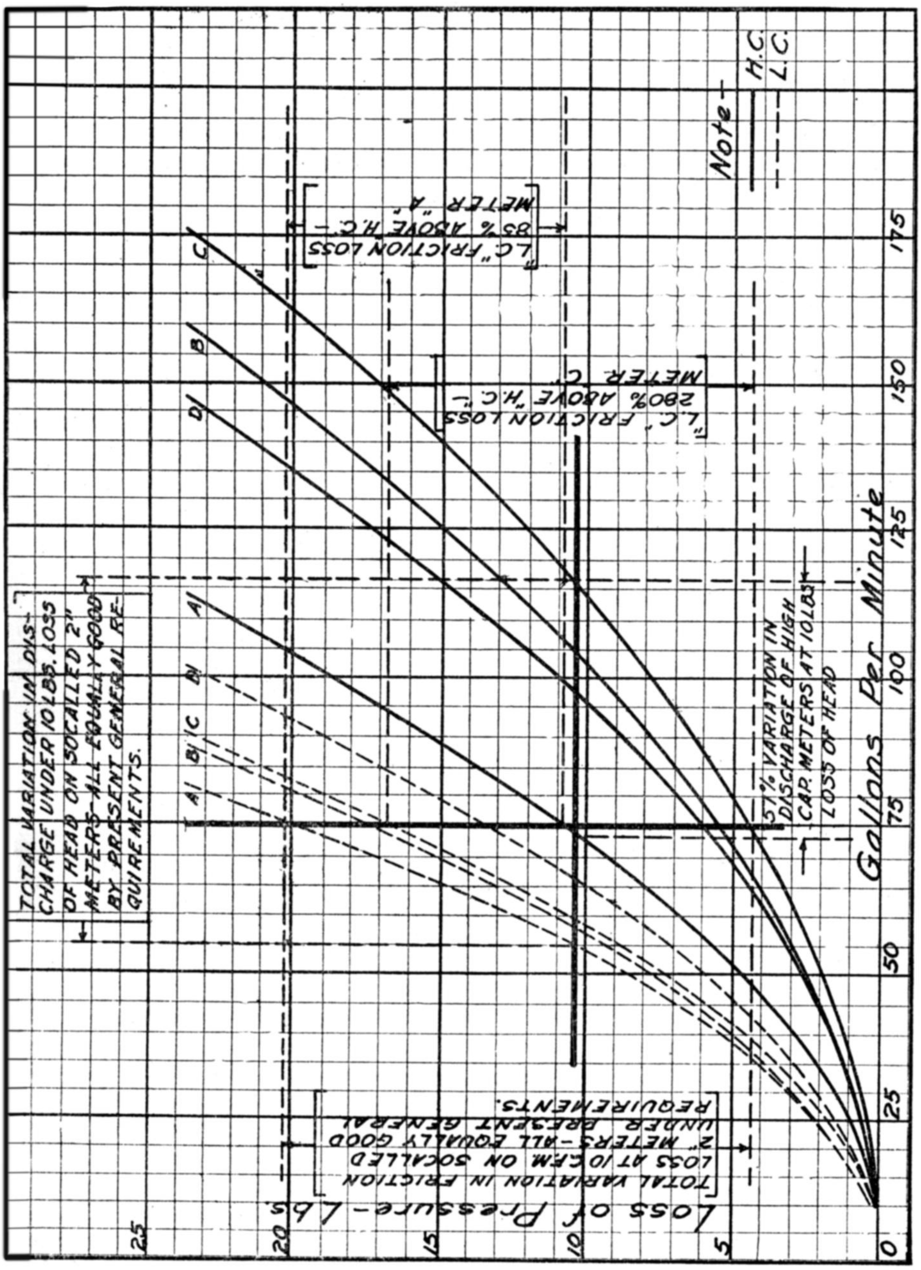

FIG. 4. VARIATIONS OF CAPACITY AND LOSS OF HEAD IN FOUR MAKES OF 2-INCH METERS
Full lines are for high-capacity and dotted lines for low-capacity meters.